J. New York Entomol. Soc. 106(2–3):69–75, 1998

GEOGRAPHIC DISTRIBUTIONS OF *PERISTENUS CONRADI* AND *P. DIGONEUTIS* (HYMENOPTERA: BRACONIDAE), PARASITES OF THE ALFALFA PLANT BUG AND THE TARNISHED PLANT BUG (HEMIPTERA: MIRIDAE) IN THE NORTHEASTERN UNITED STATES

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Abstract.—*Peristenus digoneutis* Loan, an introduced parasite of the tarnished plant bug, *Lygus lineolaris* (Palisot) (a native species), has spread from its original establishment point in northwestern New Jersey into six additional states. It has been found in 36 counties, but likely is more widespread. Its dispersion has mostly been to the northeast, and has not occurred south of latitude 40°N. *Peristenus conradi* Marsh, an introduced parasite of the alfalfa plant bug, *Adelphocoris lineolatus* (Goeze) (an introduced insect), has spread from its initial establishment location in northern Delaware into two other states. It is known from a total of nine counties, but probably also is present in others. Both parasitic wasp species are now established widely enough that field studies can be conducted in several states.

Key words: *Adelphocoris*, alfalfa, *Lygus* spp., parasites, *Peristenus* spp.

Two species of European parasites of mirid plant bugs have recently become established in the northeastern United States. Both are braconid wasps—*Peristenus digoneutis* Loan, a parasite of *Lygus* nymphs (Day et al. 1990), and *P. conradi* Marsh, a parasite of *Adelphocoris* nymphs (Day et al. 1992).

Since these initial reports, these two wasps have continued to disperse, and our limited surveys have found them in a total of six new northeastern states and in 40 additional counties. These results are reported in this paper, and are the results of surveys by all of the authors. Such geographic range data are used to estimate the rate of dispersion (which cannot be done in the country of origin), and to determine if a species' climatic limits have been reached. And once an introduced insect is known to be present in a new area, field ecological studies can be started.

MATERIALS AND METHODS

Surveying for geographic range of parasites. Timing of field sampling is especially important, for maximum efficiency. Sampling at peak parasitism will provide the largest number of parasites, for the best chance of detecting a "new" species. Peak parasitism occurs at or near the population peak of the mirid nymphs (Day, unpubl.),

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which also provides the largest sample of hosts. Because *P. conradi* only parasitizes first generation *Adelphocoris* (Day et al., 1992), and *P. digoneutis* parasitizes first and second generation *Lygus* (Day et al., 1990), field surveys were scheduled for periods when these events were expected to occur. As the growing season advanced from south to north, our surveys gradually moved northward also. Weekly samples of mirid nymphs throughout each year, at two or three locations, assisted in predicting the dates when each species would reach maximum numbers.

A safety glass-topped sleeve cage (Day et al., 1990) was used to prevent escape of the swept mirids while they were being identified, counted, and collected, and to retain adult parasites. Swept *P. digoneutis* adults were identified with a hand lens in the field, greatly speeding up the survey (further sampling in the same county was therefore not necessary). Identification of *P. conradi* adults requires 20–30× magnification, which is usually done with a binocular microscope in the laboratory, but identification of swept adults still provides new location records much faster than conventional rearing (which requires 10 months because of the obligatory diapause of all *P. conradi*, and of most *P. digoneutis*).

Plant bug numbers varied from one alfalfa field to another, but were nearly always higher in older fields and in taller alfalfa (Day, unpubl.), so sweeping was concentrated in such fields when they were available. Counties to be sampled were selected because they were adjacent to counties where the parasite had previously been detected, or were along the northeastern direction of parasite dispersion.

Sampling. The minimum sample per field was 100 half-cycle sweeps with a 37-cm dia. beating net. Most *P. digoneutis* were reared from *L. lineolaris*, and most *P. conradi* were reared from *A. lineolatus*, but all seven mirid species which were commonly swept in alfalfa, alfalfa-grass, and red clover fields were retained (these species are named in Table 3). Surveys were made in the years listed in Table 1. In addition to samples from these special surveys, regular weekly or biweekly samples were taken throughout the growing season at several locations to determine the timing of parasite occurrence in the field, which differs slightly from year to year. This monitoring was done near Blairstown, NJ (*P. digoneutis*, 1981–1994), at Newark, DE (*P. conradi*, 1988–1994), and near Woodstown, NJ (*P. conradi* 1988–1994). Native parasites were sampled in the same way at all 3 locations.

Each sample of nymphs was reared to determine the species of parasite present (Day, 1994). The three alfalfa-feeding mirids (*Adelphocoris*, *Halticus*, & *Lygus*) were fed alfalfa "bouquets," and the four grass-feeding mirids (*Leptopterna*, *Megalocerooea*, *Stenotus*, & *Trigonotylus*) were fed grass foliage and seed heads. Rearing procedures and cages were as outlined in Day (1996).

Healthy nymphs, as well as those injured during collecting that were not likely to survive the rearing process, were frozen at −20°C for later dissection (Day, 1994), to determine the degree of parasitism. These results will be reported elsewhere.

RESULTS AND DISCUSSION

Distribution of *Peristenus digoneutis*. Previously, this introduced parasite of *Lygus lineolaris* was known to be present in three counties, in two states (New Jersey and New York; Day et al., 1990). Since that time, we have found it in an additional five states (Pennsylvania, Massachusetts, New Hampshire, Vermont, and Connecticut),

Table 1. First county and state recoveries of *Peristenus digoneutis*.

State	County	Nearest town	Parasitized host collected	
			Date	By
NJ	Warren	Marksboro	7/06/84	Day
NJ	Sussex	Fredon	6/16/88	Day
NY	Orange	Warwick	7/07/89	Day
NJ	Morris[a]	Long Valley	7/28/92	Chianese & Crowley
(DE	New Castle	Newark	7/13/92	Day & Tropp)[b]
NY	Ulster	Wallkill	6/23/93	Day
PA	Northampton	Wind Gap	6/16/93	Day
MA	Franklin	Deerfield	6/29/93	Van Driesche & McCool
	Hampden	Agawam	8/04/93	Van Driesche & McCool
NJ	Hunterdon	Hampton	8/03/93	Chianese & Crowley
PA	Monroe	Kresgeville	7/26/94	Romig
NY	Albany	Preston Hollow	8/02/95	Day
	Columbia	Hudson	6/14/95	Tropp
	Delaware	Lake Delaware	8/01/95	Day
	Dutchess	Hibernia	6/08/95	Tropp
	Greene	Coxsackie	6/14/95	Tropp
	Renssalaer	Poestenkill	8/01/95	Tropp
	Schoharie	North Blenheim	8/02/95	Day
NH	Hillsborough	Milford	7/26/95	Eaton
PA	Carbon	Beltzville	7/25/95	Romig
VT	Bennington	S. Shaftsbury	8/02/95	Tropp
	Windham	Vernon	8/02/95	Tropp
CT	Hartford	Suffield	7/20/95	Tropp
	Litchfield	Bakersfield	7/19/95	Tropp
NY	Broome[a]	Itaska	7/09/96	Tropp
	Clinton	W. Chazy	7/10/96	Tropp
	Oneida	Paris Station	8/21/96	Tropp
	Otsego	Richfield Stat.	8/24/96	Tropp
	Saratoga	Waterford	7/23/96	Tropp
	Washington	Easton	7/23/96	Tropp
NH	Belknap	Belmont	8/23/96	Eaton
	Grafton	Orford	8/22/96	Eaton
	Merrimac	Concord	8/15/96	Eaton
	Rockingham	Epping	8/14/96	Eaton
	Strafford	Madbury	8/09/96	Eaton
PA	Luzerne[a]	Conyngham	8/06/96	Romig
	Wyoming	Factoryville	8/14/96	Romig

All records are based on reared female parasites, unless otherwise noted below.

[a] Tentative, based on male only (swept or reared).

[b] Reared from nymphs collected in 1992 and 1993, but not in 1994 and 1995, so not counted as established here.

and in 33 more counties (Table 1). Fig. 1 shows the minimum range (dates within counties) and probable range limits (dates within lines) of *P. digoneutis*. The probable range limits are slightly larger than the known recovery counties because the parasite was detected in 100% of the counties that we surveyed in 1995, and in 59%

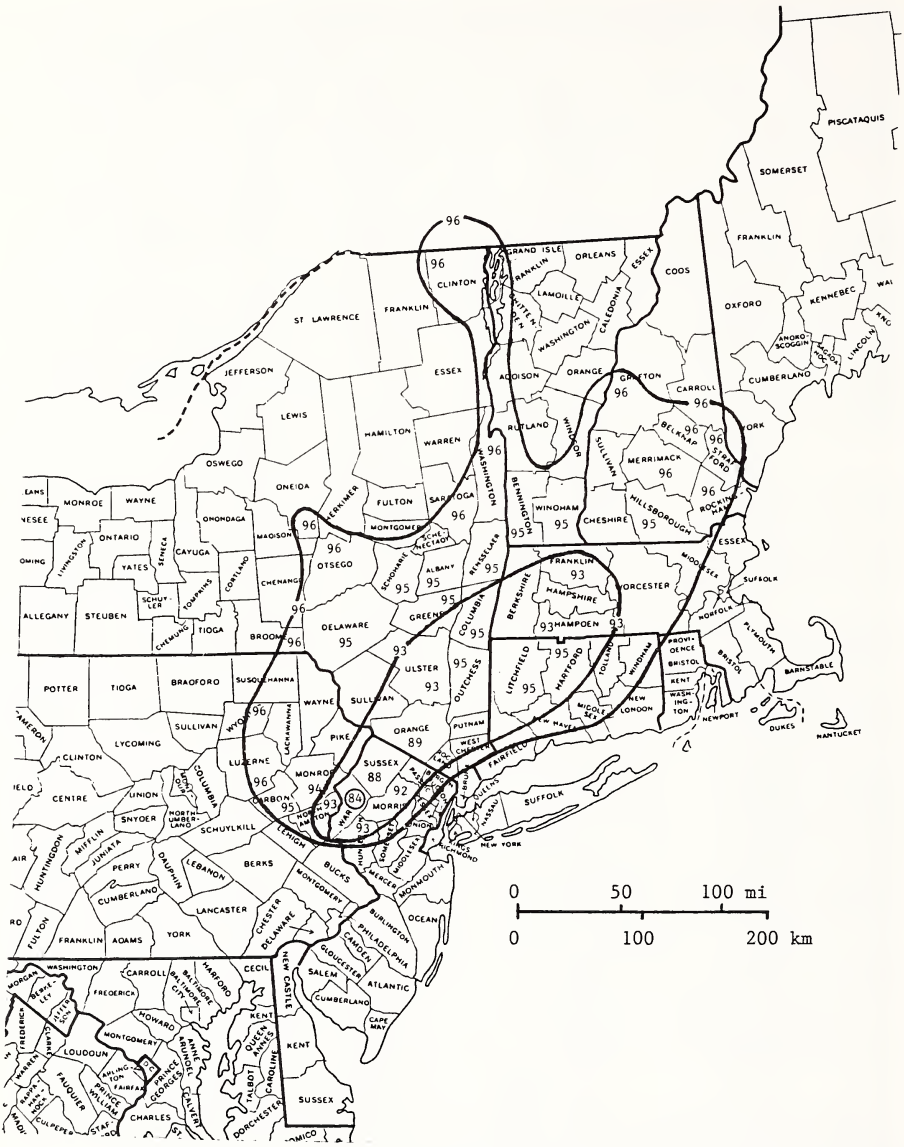

Fig. 1. Known and possible dispersion of *Peristenus digoneutis*, June 1997. The circled date shows the location and year where this parasite was first found to be permanently established in North America. Uncircled dates indicate when the parasite was first collected in each county. Years within the range line depict the probable dispersion by that year.

Table 2. First county and state recoveries of *Peristenus conradi.*

State	County	Nearest town	Parasitized host collected	
			Date	By
DE	New Castle	Newark	5/30/88	Day & Saunders
NJ	Burlington	Juliustown	5/31/90	Day & Saunders
NJ	Gloucester	Harrisonville	5/12/92	Tropp
	Monmouth	Marlboro	6/17/92	Day
NJ	Salem	Cohansey	6/04/93	Tropp
	Middlesex[a]	Cranbury	6/10/93	Day
NY	Ulster	Wallkill	6/23/93	Day
	Dutchess	Hyde Park	6/24/93	Day
NJ	Cumberland	Carmel	6/02/94	Tropp

[a] Based on a swept adult parasite only. The others are based on reared adult parasites.

of those sampled in 1996 (most of the counties lacking *P. digoneutis* in 1996 were represented by few field samples and/or small sample sizes): more negative counties would be expected if we had sampled past the "leading edge" of the *P. digoneutis* dispersion pattern.

The probable distribution of *P. digoneutis* (Fig. 1) now encompasses approximately 115,000 km^2 (45,000 mi^2). Most of its natural dispersion has been to the northeast. Probably this is a result of two factors: the prevailing summer wind direction from the southwest, and the apparent inability of this species to survive in the warmer climate to the south (the parasite has only moved about 48 km [30 mi] south, in 12 years). This limit is approximately at 40.5° latitude, considerably south of the latitude (45°) where *P. digoneutis* was originally collected in Europe (its southern distributional limits there are unknown). Although genetic selection may eventually allow this parasite to move farther south, in the near future effective biological control of *Lygus* by *P. digoneutis* (Day, 1996) will probably be limited to the northern United States and southern Canada.

Distribution of *Peristenus conradi.* Initially, we detected this introduced parasite in just one county, in each of two states (Delaware and New Jersey; Day et al., 1992). Subsequently, our limited surveys have found it in a third state (New York), and in seven additional counties (Table 2). Because time has not permitted more extensive field surveys, the range of *P. conradi* is likely larger than depicted in Fig. 2. However, intensive and season-long sampling of *Adelphocoris* nymphs in Warren and Sussex counties in New Jersey from 1981–1996 (Day, unpubl.) has not detected *P. conradi* there, so it is not present in all counties between the original establishment point in northern Delaware and the 1993 recoveries in southeastern New York (Fig. 2). We have not sampled to the south, west, or north of Delaware, so nothing is known of its dispersion in those directions, nor of its climatic limits.

Biologies of parasites. To facilitate sampling in the future, key information for the three native and two introduced species of parasites is provided in Table 3. The dates that each wasp occurs in the field vary with cumulative temperature, and with dates of mowing the alfalfa (early mowing and short mowing intervals each reduce mirid numbers, so indirectly reduce parasite numbers later). Abundance of the preferred mirid host also varies with the plant species (for example, new fields planted to only

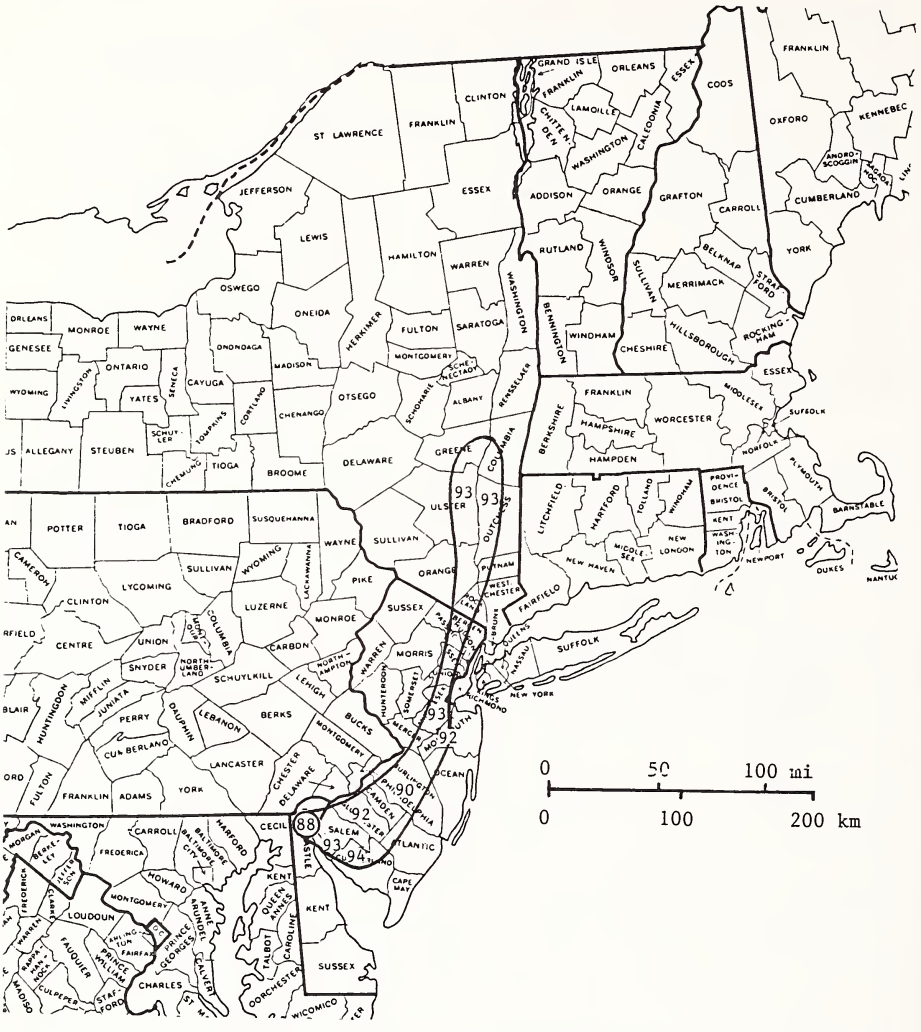

Fig. 2. Known dispersion of *Peristenus conradi*, March 1997. The circled date shows the location and year where this parasite was first found to be permanently established in North America. Uncircled dates indicate when the parasite was first collected in each county. The line depicts the probable range of this species.

alfalfa will not have any grasses or *Erigeron* [Table 3], so *P. pallipes* and *P. pseudopallipes* will be rare or absent).

The natural spread of *P. conradi* and *P. digoneutis* observed to date suggests that both species will continue to disperse in the northeastern states. The faster dispersion of *P. digoneutis* indicates that at present, ecological studies of this species can be conducted at more locations, and over a greater range of environmental conditions, compared to *P. conradi*.

Table 3. Summary of biologies of braconid parasites of alfalfa and grass-feeding mirids, used to determine appropriate sampling dates and hosts.

Parasite species	Generations			No. sexes	Major association	
	Native	No./yr[a]	Months[a]		Plant	Mirid[b]
Peristenus conradi Marsh		1	May	1[c]	alfalfa	APB
P. pallipes (Curtis)	+	1	May	2	grasses	GPB
P. digoneutis Loan		2–3	Jun–Aug	2	alfalfa	TPB
P. pseudopallipes Loan	+	1	Jul–Aug	2	Erigeron[d]	TPB
Leiophron uniformis (Gahan)	+	2–3	Jul–Aug	2	alfalfa	GFH

[a] Period that parasite larvae and adults are present in the field, at 39°–41°N latitude (determined at two monitoring sites in New Jersey, and one in Delaware).

[b] GFH = garden fleahopper, *Halticus bractatus* (Say); APB= alfalfa plant bug, *Adelphocoris lineolatus* (Goeze); TPB = tarnished plant bug, *Lygus lineolaris* (Palisot); GPB = grass plant bugs, *Trigonotylus coelestialium* (Kirkaldy) and *Leptopterna dolabrata* (L.). Two additional species were not significantly parasitized: *Megaloceroea recticornis* (Geoffroy) and *Stenotus binotatus* (F.).

[c] Over 99% are female.

[d] Fleabane, horseweed (Asteraceae), in or near alfalfa fields.

ACKNOWLEDGMENTS

We thank T. Blasi, H. Crowley, J. McCool, R. Neal, and L. B. Saunders for technical assistance, and N. L. Brady for typing. We greatly appreciate the use of fields of the following alfalfa growers (G. W. & G. H. Fee, H. & J. Crisman, J. Vough, & W. Vosper), and cultural operations and the use of University of Delaware alfalfa fields (T. Timko & J. Wolfer). We thank C. R. Baird, N. J. Bostanian, R. J. Dysart, and C. H. Pickett for their suggestions to improve an earlier version of this paper.

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Received 25 November 1997; accepted 17 June 1998.